Reactive Brazing of Carbon-Carbon Composites to Titanium

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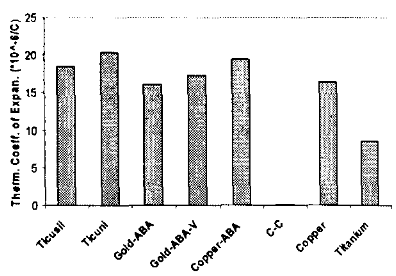
- **Objective:**
  - To investigate and optimize active metal brazing of Carbon-Carbon Composites to Titanium.
- **Approach:**
  - Examine the microstructure and composition of the brazed joints using optical and scanning electron microscopy (SEM) coupled with EDS.
  - Determine the strength of the joints using a tube-plate tensile test.

Brazing and Assembly Technologies are Critical for Scale-up and Manufacturing

- Carbon-Carbon composites and metallic components have to be brazed for heat rejection system components.
- Due to differences in thermal expansion coefficients of C/C composites and metallic components following issues have to be addressed.
  - *Braze composition and compatibility*
  - *Joint design*
  - *Mechanical testing and characterization*
  - *Thermal and environmental durability testing*



- ***Thermal expansion coefficients of some commercially available brazes, C/C, and metals.***
- ***The chart demonstrates the need for innovative joint design concepts, new braze materials, and robust brazing technology development to avoid deleterious effects of thermal expansion mismatch.***

Active Metal Brazing of C/C Composites to Metallic Components

In the brazing of C/C composites and metallic components following issues are being addressed.

- *Braze Joint Composition and Compatibility*
- *Joint Design and Interfacial Characterization*
- *Mechanical Testing and Characterization*
  - Tensile Tests, Shear Tests
- *Thermal and Environmental Durability Testing*

Systems Investigated in the Present Study

- Resin derived and CVI C/C composites reinforced with T-300 Carbon fibers.
- Titanium tubes and plates.
- TiCuSil™, Copper-ABA, and TiCuNi braze materials

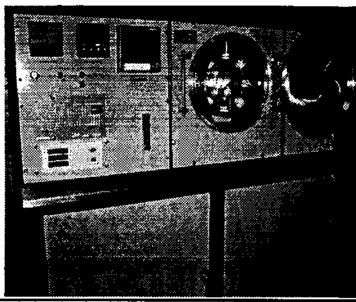
Assembly and Brazing Technology Development

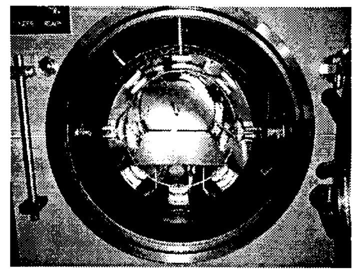
Braze Compositions:

- TiCuSil : $Ag_{68.8}Cu_{26.7}Ti_{4.5}$; Liquidus: 900 C
- TiCuNi : $Ti_{70}Cu_{15}Ni_{15}$; Liquidus: 960 C
- Copper-ABA: $Cu_{92.75}Ti_{2.25}Al_{2}Si_{3}$; Liquidus: 1024 C

Brazing Conditions:

- Vacuum: 10^{-6} Torr
- Braze Temperature: T+ Liquidus

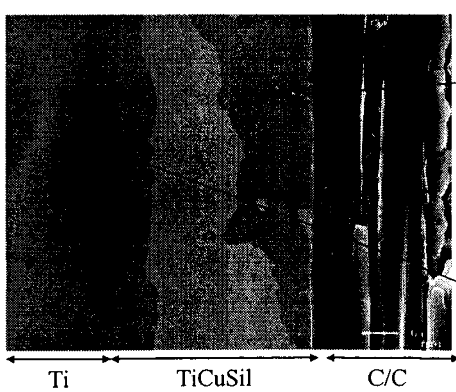


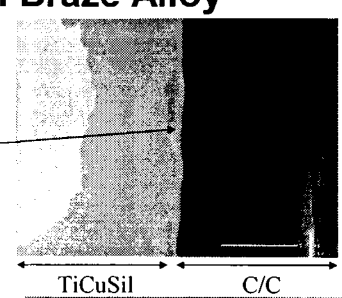


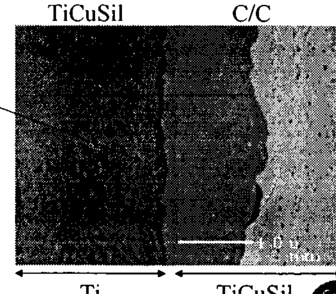
Brazing Chamber

Vacuum Brazing Furnace

Bonding of Titanium with C/C Composites using TiCuSil- Active Metal Braze Alloy



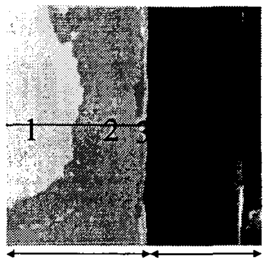




- Good bonding was observed at the titanium and C/C interfaces.

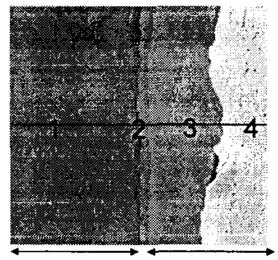
EDS Analysis: Ti joined to C/C Composite using TiCuSil

Composition of TiCuSil: 69% Ag, 27% Cu, 4% Ti



Composition:

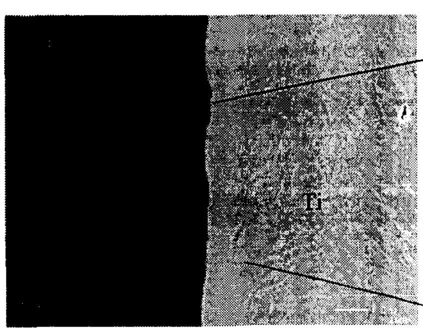
1) 84%Ag, 9%Cu, 7%Ti
2) 8%Ag, 54%Cu, 38%Ti
3) 24%Ag, 76%Ti
4) 100%C

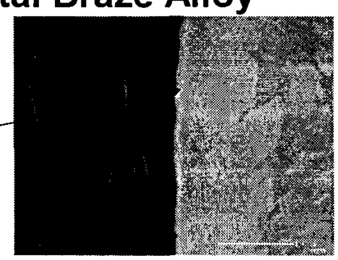


Composition:

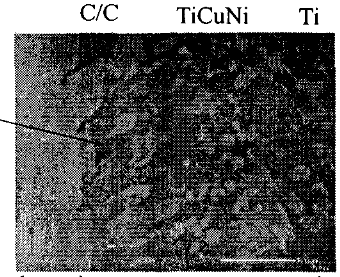
1) 87%Ti, 13%Ag
2) 52%Ti, 29%Cu, 19%Ag
3) 38%Ti, 48%Cu, 14%Ag
4) 6%Ti, 94%Ag

Bonding of Titanium with C/C Composites using TiCuNi- Active Metal Braze Alloy



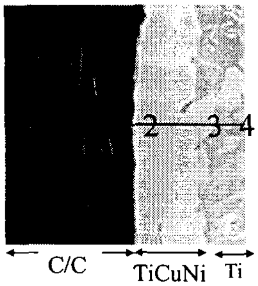


•Good interaction and diffusion of braze into substrates

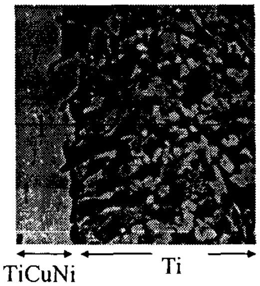


EDS Analysis: Ti Joined to C/C Composite using TiCuNi

Composition of TiCuNi: 70% Ti, 15% Cu, 15% Ni

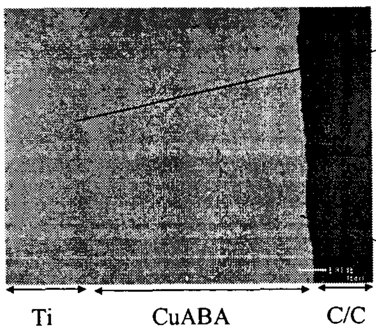


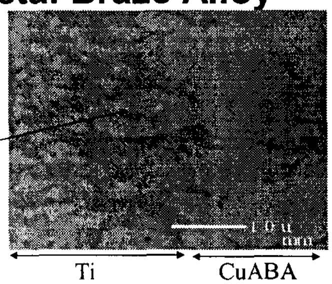
Composition:
1) 100% C
2) 61%Ti, 28%Cu, 11%Ni
3) 40%Ti, 33%Cu, 27%Ni
4) 50% Ti, 26%Cu, 24%Ni

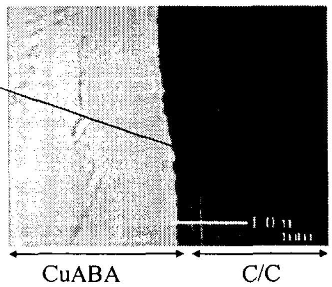


Composition:
1) 44%Ti, 24%Ni, 32%Cu
2) 41%Ti, 22%Ni, 37%Cu
3) 57%Ti, 16%Ni, 27%Cu
4) 43%Ti, 35%Ni, 22%Cu

Bonding of Titanium with C/C Composites using CuABA-Active Metal Braze Alloy



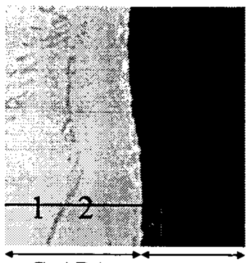




•Very good interaction and diffusion of Cu-ABA into Titanium.

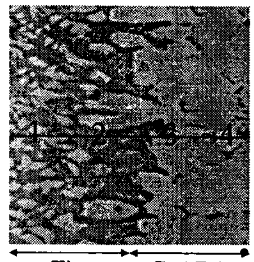
EDS Analysis: Ti joined to C/C Composite using Cu-ABA

Composition of Cu-ABA: 93% Cu, 3% Si, 2% Ti, 2% Al



Composition:

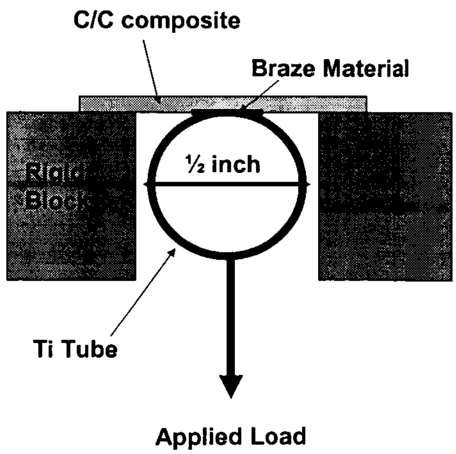
1) 38%Cu, 54%Ti, 4%Si, 4%Al
2) 65%Ti, 26%Cu, 5%Si, 4%Al
3) 78%Ti, 17%Cu, 3%Si, 2%Al
4) 100%C



Composition:

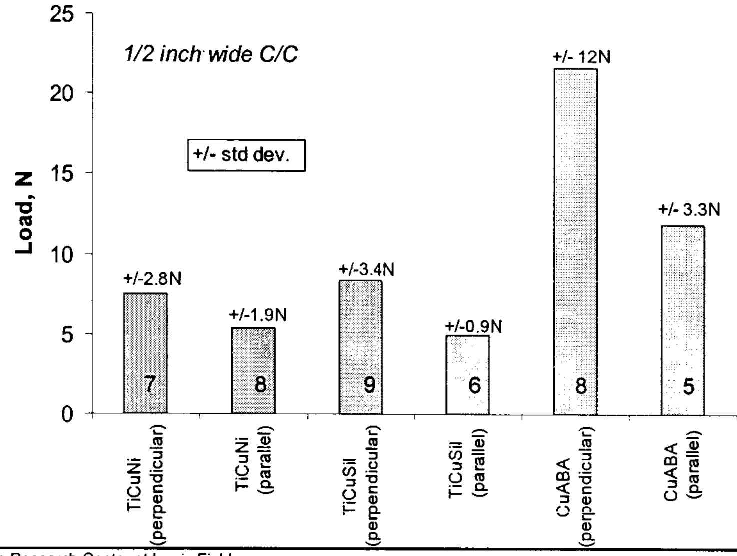
1) 80%Ti, 13%Cu, 6%Al, 1%Si
2) 86%Ti, 11%Cu, 2%Al, 1%Si
3) 61%Ti, 35%Cu, 2%Al, 2%Si
4) 57%Ti, 40%Cu, 1%Al, 2%Si

Mechanical Testing



A schematic of the tensile test method used. A number of designs were investigated but this proved to be the most reliable.

Load Carrying Capability of Joints in Tension: Different Fiber Orientations



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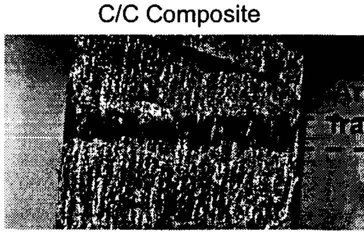
Fracture Surface of Cu-ABA and TiCuNi

C/C Composite

Ti Tube

Fracture surface of CuABA test samples



C/C Composite

Ti Tube

Fracture Surface of TiCuNi test Sample

The highest failure loads corresponded to the largest fracture areas

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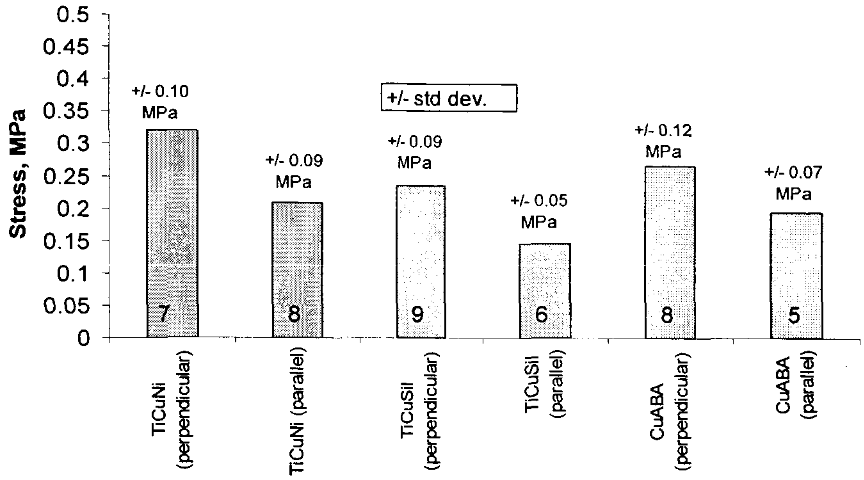
Tensile Test Stress Results: Fiber Orientation Varied



Conclusions

- All Samples appear to have adequate bonding between the C/C composite and titanium substrates.
- According to the tensile data the CuABA braze exhibits the highest load carrying capability due to the high contact area after brazing.
- The strength of the joint is limited by the interlaminar shear strength (ILSS) of the C/C composite. Failure occurs within the composite.

Future Work

- Additional room and high temperature mechanical testing will be performed to determine the optimal testing method.
- Other possible brazes are currently being investigated.
- Modifications are being incorporated to increase braze contact area.

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ACTIVE METAL BRAZING OF CARBON-CARBON COMPOSITES TO TITANIUM

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ABSTRACT

The Ti-metal/C-C composite joints were formed by reactive brazing with three commercial brazes, namely, Cu-ABA, TiCuNi, and TiCuSil. The joint microstructures were examined using optical microscopy, and scanning electron microscopy (SEM) coupled with energy dispersive spectrometry (EDS). The results of the microstructure analysis indicate solute redistribution across the joint and possible metallurgical bond formation via interdiffusion, which led to good wetting and spreading.